Planting Rate and Nitrogen Fertility Affect Runoff Losses during Hybrid Bermudagrass Establishment

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Core Ideas
- The high sprig planting rate resulted in faster bermudagrass establishment.
- The high and low N fertilizer rates resulted in similar bermudagrass establishment.
- Runoff, sediment, and nutrient losses decreased over time as groundcover increased.
- High sprigging and low N fertilization rates reduce nutrient losses during establishment.

ABSTRACT
Bermudagrass is grown on athletic fields, home lawns, and right-of-ways because of its quality, excellent wear tolerance, and vigorous growth. Sprigging followed by high N application rates is used for large acreage sites to accelerate bermudagrass establishment. However, low plant density, high soil moisture, and frequent fertilizer applications during establishment present conditions prone to sediment and nutrient movement during intense rainfall. This research simulated sprig establishment conditions while measuring bermudagrass coverage, runoff volume, and concentrations of inorganic N, total P, and sediment during 30-min rainfall events at 10, 20, and 30 days after planting (DAP) from replicate trays of bermudagrass established at 27.2 or 81.5 m³ ha⁻¹ and fertilized at 12.2 or 48.8 kg N ha⁻¹ wk⁻¹. All treatment combinations of sprig planting rates and N rates resulted in >88% bermudagrass groundcover at 35 DAP. Increasing sprig planting rates accelerated bermudagrass establishment, whereas increasing N fertility did not. As bermudagrass groundcover increased, surface runoff volume and sediment losses declined. However, sprigs fertilized at 48.8 kg ha⁻¹ wk⁻¹ N resulted in higher cumulative N losses of 2.34 and 1.48 kg ha⁻¹ compared with 1.08 and 0.68 kg ha⁻¹ for sprigs fertilized at the low fertility rate. Increasing the sprig planting rate was effective in reducing erosion. Decreasing the N application rate and increasing the planting rate during bermudagrass sprig establishment are best management practices to accelerate bermudagrass canopy closure and reduce potential nutrient and sediment losses.

Abbreviations: DAP, days after planting; TP, total phosphorus.

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Bermudagrass is a dense, vigorous turfgrass with excellent heat, drought, and wear tolerances (Kowalewski et al., 2015; Su et al., 2013) for athletic fields, home lawns, and right-of-ways in the southern United States. However, unlike common bermudagrass species, which are propagated through seed, many high-quality bermudagrass cultivars are vegetatively propagated through sod or sprigs (McCarty and Miller, 2002). Sod provides immediate soil coverage with a relatively short establishment period but becomes more expensive as acreage increases (Patton et al., 2004). The alternative is sprigging, which is a vegetative propagation method that uses segments of rhizomes and stolons. Sprigging has a longer establishment period but is a more economical method for large areas (Munshaw et al., 2017; Taylor, 2014). In an effort to achieve full groundcover quickly, it is common practice for turfgrass managers to apply high rates and frequencies of both N fertilizer and irrigation (Guertal and Evans, 2006; Hay et al., 2007).

A practice that has been reported to consistently shorten the duration of bermudagrass establishment from sprigs is to increase the planting rate (Brede, 2000; Johnson, 1973). Studies (Johnson, 1973; Texas Cooperative Extension, 1989) have suggested higher planting rates of ‘Tifway’ bermudagrass leads to faster establishment. One study indicated that planting rates up to 148 m³ ha⁻¹ hasten coverage but that rates between 29.6 and 88.8 m³ ha⁻¹ are sufficient to establish bermudagrass within 10 to 12 wk after planting (Texas Cooperative Extension, 1989). Recent studies that have examined establishment parameters for more vigorous bermudagrass cultivars support previous findings that increasing planting rates consistently leads to more rapid bermudagrass establishment (Guertal and Evans, 2006; Munshaw et al., 2017) but indicate that the effects of high N fertility are less obvious. For example, a study conducted in four states in the southeastern United States to evaluate four planting rates and four N fertility regimens on bermudagrass establishment reported that increasing the planting rate to 81.5 m³ ha⁻¹ was more effective in accelerating sprig...
establishment than applying high N rates in combination with low planting rates (Munshaw et al., 2017).

Although several published studies examining parameters for bermudagrass sprig establishment clearly indicate that increasing planting rate is a more important factor than increasing N fertility, it is common that high N rates are recommended (Alabama Cooperative Extension, 2008; University of Tennessee Extension, 2007; Virginia Cooperative Extension, 2009) to ensure adequate N across differing soil textures and/or for vigorous cultivars. Regardless, nutrients applied at rates above plant requirements are subject to offsite movement (Easton and Petrovic, 2004; Linde and Wäschke, 1997; Shuman, 2002). Excess nutrients such as N and P transported into surface waters have unintended negative environmental consequences, and the likelihood of such loading is greater in areas that receive high amounts of annual precipitation.

Offsite movement of nutrients from various horticultural and agronomic crops has been extensively reported (Baker and Laflen, 1982; Bilderback, 2002; Easton and Petrovic, 2004; Nicholaichuk and Read, 1978; Shuman, 2002; Zhu et al., 1989). However, for turfgrass, dense coverage reduces surface runoff and traps suspended sediments to minimize pollutant transport (Burwell et al., 2011; Gross et al., 1991; Kreinitsky et al., 1998; Morvan et al., 2014). Sward density greatly affects the occurrence and severity of runoff and thus nutrient movement (Easton and Petrovic, 2004). Conditions of low plant density, high soil moisture, and increased fertility that occur during bermudagrass sprig establishment make a site highly susceptible to runoff and to nutrient and sediment movement. Therefore, the objectives of this study were to determine the effects of sprig planting rate and N fertility on hybrid bermudagrass establishment and the resulting nutrient and sediment losses in runoff to develop best management practices for bermudagrass establishment from sprigs.

**MATERIALS AND METHODS**

**Experiment Setup, Sprig Planting Rates, and Nitrogen Rates**

Experiments were initiated 5 June 2018 and 2 Sept. 2018 at the Louisiana State University Agricultural Center Botanic Gardens in Baton Rouge, LA (30°24′25.3″N, 91°06′09.5″W) to examine the effects of planting rate and N fertilization on establishment of ‘Latitude 36’ bermudagrass (Cynodon dactylon (L.) Pers. × transvaalensis Burtt-Davy var. Latitude 36 Turf Bermudagrass) (US PP24,271 P3), referred to hereafter as Latitude 36 or bermudagrass.

Steel runoff trays (1.8 m width × 6.1 m length × 0.35 m depth) were placed under a rainout shelter and filled with an A horizon material of an Ohrprairie silt loam (fine-silty, mixed, semiaactive, thermic Fragiqualf Glossudalfs). Trays were inclined 3° and subdivided into 1.4-m² plots with wooden inserts. Prior to planting sprigs, soil samples were analyzed at the LSU AgCenter Soil Testing and Plant Analysis Laboratory for pH (1:1, soil/water; 7.2 ± 0.2) and for Mehlich III concentrations of P (68 mg kg⁻¹ ± 19) and K (172 mg kg⁻¹ ± 9). The soil surface was prepared by tilling and raking prior to planting sprigs. Latitude 36 was established at sprig planting rates of either 27.2 or 81.5 m⁻² and fertilized at 12.2 or 48.8 kg N ha⁻¹ wk⁻¹ using a granular ammonium sulfate (21–0–0) at 7, 14, 21, and 28 d after planting (DAP). Sprigs planted at 27.2 m⁻² and fertilized at 48.8 kg N ha⁻¹ wk⁻¹ represented the current industry practice (Munshaw et al., 2017). Each treatment combination of planting rate and N rate was replicated three times. During the first 10 DAP, plots were irrigated up to five times per day with 3.6 L using watering cans to prevent runoff. Thereafter, plots were irrigated as needed based on visual inspection of sprigs.

**Rainfall Simulation, Measurements, and Analyses**

Runoff collection systems consisted of two stainless steel right-angle inserts attached to the tray lip that directed flow through polyvinyl chloride gutters into 68-L plastic containers. Rainfall was produced using a modification of the simulator system designed by Miller (1987) and Humphry et al. (2002) that allowed simultaneous rainfall over multiple plots. In particular, four stainless steel nozzles (2HH-SS30WSQ, Spraying Systems Co.) positioned above each tray delivered 7.6 cm h⁻¹ for 30 min per event at 10, 20, and 30 DAP.

Prior to each rainfall simulation, bermudagrass groundcover was quantified using a quadrate fitted with 1 cm × 1 cm wire mesh used to note the presence or absence of bermudagrass at 100 premarked cross-sections. After each rainfall simulation, total runoff water volume was determined gravimetrically with 1-L subsamples that were collected and stored at 5°C until nutrient and sediment analyses were completed.

Water samples were analyzed for total solids (referred to henceforth as sediment), inorganic N (NH₄⁺–N + NO₃⁻–N), and total P (TP) for each treatment for the three rainfall simulations per experimental run. Sediment analysis was performed at the LSU AgCenter W.A. Callageri Environmental Laboratory following USEPA Method 106.2 (USEPA, 1999). Inorganic N was determined using the microplate method of Hood-Nowotny et al. (2010). Total P was determined colorimetrically (Murphy and Riley, 1962) after persulfate digestion (Pote et al., 2009).

Bermudagrass groundcover, shoot biomass, and tiller density were measured at 35 DAP. Shoot biomass was based on harvest from a 6.35-cm² area dried for 72 h at 55°C. Tiller densities for each plot were measured in a 2.5-cm² area.

**Statistical Analyses**

The design was completely randomized for the fixed effects of sprig planting rate and N rate. The experimental run was considered random. Data were analyzed using the MIXED procedure of SAS 9.4 (SAS Institute) for single-date measurements of bermudagrass biomass and tiller density. Measurements that occurred over time for groundcover, runoff volume, and losses of sediment, inorganic N, and TP at 10, 20, and 30 DAP were completed in the MIXED procedure of SAS using repeated measures. All mean separations followed Tukey’s HSD at $P \leq 0.05$. Data for runoff depth and sediment loads from all experimental units and runs were regressed against bermudagrass groundcover using the PROC REG procedure in SAS to determine the appropriate linear model.

**RESULTS**

**Bermudagrass Establishment**

All treatment combinations led to >88% ground cover 35 DAP (Fig. 1); however, the increasing ground coverage for the higher planting rate remained significantly greater than for the lower rate until 30 DAP, and within each planting rate there was no effect of N fertilization rate. Shoot biomass at 35 DAP was not significantly affected by treatment but ranged from 194.4 for the low sprigging and N fertilization rates to 307.2 kg ha⁻¹ for the high rates (Table 1).
Similarly, tiller density numerically increased with sprigging and N fertilization rates and was significantly greater for sprigs planted at 81.5 m$^3$ ha$^{-1}$ and fertilized with 48.8 kg N ha$^{-1}$ wk$^{-1}$ than for sprigs planted at 27.2 m$^3$ ha$^{-1}$ (Table 1).

**Surface Runoff and Sediment Losses**

Increasing bermudagrass groundcover decreased runoff depth and sediment load (Fig. 2). Runoff depth did not decrease until groundcover exceeded 60%, whereas sediment losses decreased linearly with increasing bermudagrass groundcover. Planting and N rates, however, had different effects on accelerating bermudagrass establishment and on reducing runoff and sediment load. Increasing the N application rate from 12.2 to 48.8 kg N ha$^{-1}$ wk$^{-1}$ led to a 19% reduction ($P = 0.0442$) in cumulative runoff over the 35-d experiments, with average runoff decreasing from 3.19 cm at 10 DAP to 1.75 and 0.93 cm at 20 and 30 DAP, respectively, as bermudagrass groundcover increased for all treatment combinations (Table 2). Increasing the planting rate did not affect runoff depth. Conversely, increasing the planting rate to 81.5 m$^3$ ha$^{-1}$ reduced sediment loading compared with sprigs planted at 27.2 m$^3$ ha$^{-1}$ and fertilized at the low N rate (Table 3). Sediment loads decreased from 318.4 kg ha$^{-1}$ at 10 DAP to 123.7 and 39.8 kg ha$^{-1}$ at 20 and 30 DAP, respectively, across all treatment combinations (Table 2). Cumulative sediment loads were consistently lower for the higher planting rate compared with the lower planting and N fertilization rate but were not different from the lower planting rate with higher fertilization (Table 3).

**Nutrient Losses in Runoff**

Nitrogen losses were higher for sprigs planted at the lower rate but fertilized at the higher N rate than for either planting rate at the lower N rate (Table 3). Runoff loss of N decreased with

<table>
<thead>
<tr>
<th>Planting rate</th>
<th>N fertility</th>
<th>Biomass</th>
<th>Tiller density</th>
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</thead>
<tbody>
<tr>
<td>m$^3$ ha$^{-1}$</td>
<td>kg N ha$^{-1}$ wk$^{-1}$</td>
<td>kg ha$^{-1}$</td>
<td>no. of tillers cm$^{-2}$</td>
</tr>
<tr>
<td>27.2</td>
<td>12.2</td>
<td>194.4a†</td>
<td>17.2b</td>
</tr>
<tr>
<td>27.2</td>
<td>48.8</td>
<td>205.6a</td>
<td>19.7b</td>
</tr>
<tr>
<td>81.5</td>
<td>12.2</td>
<td>210.3a</td>
<td>23.0ab</td>
</tr>
<tr>
<td>81.5</td>
<td>48.8</td>
<td>307.2a</td>
<td>27.2a</td>
</tr>
</tbody>
</table>

† Means in a column followed by different letters are significantly different (Tukey’s HSD; $P \leq 0.05$).

Fig. 2. Effect of ‘Latitude 36’ bermudagrass groundcover on runoff depth (A) and sediment (B) loading from 30-min rainfall simulations on sprigs at 10, 20, and 30 d after planting.

**DISCUSSION**

Practices that accelerate bermudagrass growth for faster canopy closure have the benefit of reducing the establishment period as well as curbing erosion and nutrient losses. In this study, increasing the planting rate of bermudagrass sprigs from 27.2 to 81.5 m$^3$ ha$^{-1}$ resulted in >88% groundcover at 20 versus 30 DAP for the low planting rate. Accelerating bermudagrass establishment through increasing planting rates has been consistently reported for various bermudagrass cultivars (Brede, 2000; Johnson, 1973; Munshaw et al., 2017). However, increasing N fertility did not sufficiently

<table>
<thead>
<tr>
<th>Days after planting</th>
<th>Runoff depth</th>
<th>Sediment</th>
<th>Total P</th>
</tr>
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<tbody>
<tr>
<td>cm</td>
<td>kg ha$^{-1}$</td>
<td>kg ha$^{-1}$</td>
<td>kg ha$^{-1}$</td>
</tr>
<tr>
<td>10</td>
<td>3.19†</td>
<td>318.4a</td>
<td>0.26a</td>
</tr>
<tr>
<td>20</td>
<td>1.75b</td>
<td>123.7b</td>
<td>0.07b</td>
</tr>
<tr>
<td>30</td>
<td>0.93c</td>
<td>39.8c</td>
<td>0.02c</td>
</tr>
</tbody>
</table>

† Means in a column followed by different letters are significantly different (Tukey’s HSD; $P \leq 0.05$).
accelerate bermudagrass growth for sprigs planted at the same rate; more importantly, fertilizing at the high N rate did not accelerate sprigs planted at 27.2 m³ ha⁻¹ to attain similar groundcover as sprigs planted at 81.5 m³ ha⁻¹ and fertilized with 75% less N. Although it is reported that high N application rates and frequencies are not required to achieve bermudagrass establishment from sprigs (Guertal and Evans, 2006), the results of this study confirm previously published work focused on similar establishment parameters examined for Latitude 36 (Munshaw et al., 2017).

If the practice of increasing N fertility did not accelerate bermudagrass sprig growth for faster canopy closure, then it is important to understand other potential benefits or drawbacks associated with higher N application. Areas in the mid-South, such as Louisiana, where annual precipitation can exceed 150 cm yr⁻¹ (US Climate Data, 2019), sediment and nutrient losses will occur during establishment on fine-textured soils due to low plant density (Burwell et al., 2011) and high soil moisture, a result of routine irrigation applied to prevent sprig desiccation. A dense turfgrass can delay the onset of surface runoff to reduce runoff volume and pollutant transport (Cole et al., 1997; Gross et al., 1990; Morvan et al., 2014) due to greater water infiltration, tortuous flow path, and entrapment of suspended sediments (Burwell et al., 2011; Linde and Wäschke, 1997), as has been illustrated by the collective data in this study (Fig. 2). Previous work with Kentucky bluegrass (Poa pratensis L.) and common bermudagrass (Cynodon dactylon L.) by Easton and Petrovic (2004) and Burwell et al. (2011), respectively, found similar results, with increasing density or groundcover correlating to declining surface runoff volume and sediment losses. However, increasing the N fertility rate did not increase bermudagrass groundcover and is therefore unjustified for this purpose. Increasing N fertility did decrease cumulative runoff volume by 19%, but the decline in cumulative runoff volume did not result in less nutrient and sediment loading for the experimental period. Surface runoff by itself is not a pollutant and serves as an important means of drainage in a landscape.

Fertilizing bermudagrass sprigs at the high N rate led to increased inorganic N losses over the establishment period but failed to hasten turfgrass growth to reduce TP and sediment losses. Furthermore, because most P losses in surface runoff from bare soil are associated with sediment movement (e.g., Sharples et al., 1993), increasing groundcover through planting rates ≥81.5 m³ ha⁻¹ shows the greatest potential for reducing erosion rather than increasing N application rates. Sprigs planted at high rates create a physical soil barrier, or mulching effect, which reduces splash erosion, a common soil disturbance process during intense precipitation that leads to greater erodibility (Marzen et al., 2015; Yao et al., 2018). However, changes in rainfall intensity, timing, and/or duration can alter nutrient and sediment loading. Schwartz and Shuman (2005) reported nutrient losses to be greatest for the first runoff event after application, especially as rainfall intensity and duration increased. In the current experiments, P was not applied in initial or subsequent fertilizations; however increasing bermudagrass groundcover through higher planting rates filtered more sediment and thus has a greater potential to reduce offsite soil-bound P transport. These results indicate that higher spigging rates not only consistently provide greater resistance to sediment bound nutrients but also potentially reduce other sediment-bound pollutants, such as pesticides that are commonly applied during spig establishment.

The response by bermudagrass spigs to the changes in N fertilization during establishment reflected changes in initial plant density and N plant uptake and utilization. High initial N losses followed by declining losses were measured for all treatment combinations from 10 to 30 DAP. This decline in N losses occurred even though sequential N applications were applied weekly and two N applications occurred between the last two rainfall simulations at 20 and 30 DAP. Nutrient uptake is governed by several factors, such as plant age, rooting, nutrient availability, and abiotic environmental factors (Alam, 1999; Baldwin, 1975; Clarkson, 1985). Sprigs are segments of stolons that have undeveloped root systems, which physically limits N uptake. Root architecture has been shown to be positively correlated to N uptake for reduced N leaching of other turfgrass species (Bowman et al., 1998). Although N uptake and utilization is not fully understood for bermudagrass sprigs during establishment, the decline in N losses between 10 and 30 DAP from increasing bermudagrass groundcover suggests that turfgrass nutrient interception for greater plant uptake and growth was a significant factor that altered surface runoff resistance and nutrient losses.

In addition to low spig density at planting, stress during the initial days after planting, commonly referred to as transplant shock, can affect nutrient uptake of various horticulture species (Jacobs and Timmer, 2005; Van Iersel, 1999). Transplant shock of bermudagrass sprigs may be similar to the findings of Sermons et al. (2017), who described changes in N uptake and utilization of bermudagrass exiting dormancy as having a greater reliance on existing plant reserves. Overall, the application of >12.2 kg N ha⁻¹ wk⁻¹ was provided no benefit in accelerating Latitude 36 bermudagrass sprig establishment as a means to reduce nutrient and sediment movement. Further study is warranted to better define N plant uptake and utilization during establishment to improve fertility guidelines.

Table 3. Effect of sprig planting rate and nitrogen fertility on cumulative losses of sediment, total phosphorus, and inorganic nitrogen from ‘Latitude 36’ bermudagrass during 30-min rainfall simulations at 10, 20, and 30 d after planting.

<table>
<thead>
<tr>
<th>Planting rate</th>
<th>N fertility</th>
<th>Sediment</th>
<th>Total P</th>
<th>Inorganic N</th>
</tr>
</thead>
<tbody>
<tr>
<td>m³ ha⁻¹</td>
<td>kg N ha⁻¹ wk⁻¹</td>
<td>kg m⁻²</td>
<td>μg</td>
<td>kg N ha⁻¹</td>
</tr>
<tr>
<td>27.2</td>
<td>12.2</td>
<td>668.0a</td>
<td>0.45a</td>
<td>1.08b</td>
</tr>
<tr>
<td>27.2</td>
<td>48.8</td>
<td>476.5ab</td>
<td>0.36a</td>
<td>2.34a</td>
</tr>
<tr>
<td>81.5</td>
<td>12.2</td>
<td>388.6b</td>
<td>0.30a</td>
<td>0.68b</td>
</tr>
<tr>
<td>81.5</td>
<td>48.8</td>
<td>394.4b</td>
<td>0.31a</td>
<td>1.48ab</td>
</tr>
</tbody>
</table>

* Means in a column followed by different letters are significantly different (Tukey’s HSD; P < 0.05).

Fig. 3. Inorganic N runoff losses from ‘Latitude 36’ bermudagrass sprigs fertilized at 12.2 or 48.8 kg N ha⁻¹ wk⁻¹ during 30-min rainfall simulations 10, 20, and 30 d after planting.

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During the establishment of bermudagrass from sprigs, surface runoff will most likely result in sediment and nutrient losses in high-rainfall climates. In such conditions, negative environmental effects can occur if attempting to compensate low spor planting rates with high N applications. However, changing establishment practices to increase planting rates and lower N fertility can mitigate nutrient and sediment losses during bermudagrass establishment. Applying N above 12.2 kg ha\textsuperscript{-1} wk\textsuperscript{-1} does not hasten bermudagrass growth sufficiently to accelerate canopy closure and leads to increased N losses, whereas increasing planting rates ≥81.5 m\textsuperscript{3} ha\textsuperscript{-1} reduces the duration of establishment for greater sward resistance to surface runoff for less erosion and sediment-bound pollutant movement.

REFERENCES


